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A NEW CONCEPT FOR CAMOUFLAGE, CONCEALMENT, AND DECEPTION USING LAMINATED PAPER GLASS (LPG) APPLIQUÉS

by

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13. ABSTRACT *(Maximum 200 words)*

This report describes the preliminary development of laminated paper glass (LPG) appliqués as a new hybrid camouflage, concealment, and deception (CCD) technology by the US Army Engineer Waterways Experiment Station. Since LPG is a composite, the CCD designer can control the fundamental physical (tensile and shear stress) and spectral (emissivity, radar scattering, thermal conductivity) characteristics to his/her advantage. This report includes a brief summary of the evolution of the LPG concept and the description of the potential employment of LPG appliqués as a signature manipulation material and as a construction material.

14. SUBJECT TERMS

Appliqués	Concealment	Laminated Paper
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Contents

Preface

The study reported herein was sponsored by Headquarters, US Army Corps of Engineers under Project No. P612784AT40, Task BO, Work Unit 079, "Camouflage Materials Evaluation and Testing."

The study was conducted by personnel of the US Army Engineer Waterways Experiment Station (WES) during the period March 1989 to March 1991, under the general supervision of Dr. John Harrison, Chief, Environmental Laboratory, (EL), Dr. Victor E. LaGarde, III, Chief, Environmental Systems Division (ESD), EL, and under the direct supervision of Mr. Malcolm Keown, Chief, Environmental Constraints Group (ECG), ESD, and Dr. Jonathan C. Duke, Jr., ECG, ESD, Technical Team Leader of the Camouflage Field Demonstration Team.

This report was prepared by Mr. Bartley P. Durst and Mr. David L. Meeker, ECG, ESD. Dr. Duke was responsible for the overall laboratory data collection effort. The WES laboratory team included Mr. Durst, Mr. Jesse B. Blalack, Mr. A. David Cook, Mr. Gerardo I. Velazquez, Mrs. E. Jeanette Farmer, Mr. Meeker, and Dr. Duke.

At the time of publication of this report, Director of WES was Dr. Robert W. Whalin. Commander and Deputy Director was COL Leonard G. Hassell, EN.

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Conversion Factors, Non-SI to SI Units of Measurement

Non-SI units of measurement used in this report can be converted to SI units as follows:

Multiply	By	To Obtain
feet	0.3048	meters
inches	2.54	centimeters
pounds (mass)	0.4535924	kilograms

1 Introduction

Background

As weapons systems become increasingly lethal because of increased accuracy, to be detected and identified is to be engageable, and thus killable. This threat exists for mobile, semi-mobile, and fixed targets. Camouflage, concealment, and deception (CCD) is a fundamental military science that offers a means to deny, delay, decoy, or otherwise disrupt the target acquisition and engagement processes. Other than optimizing the use of environmental features and controlling operational signatures, the utility of the camofleur is a materials-limited science. Currently, CCD materials can be divided into two primary cost and technology categories: low-cost and simple (e.g., paints and nets), and expensive and exotic (e.g., coatings, radar-absorbing materials, and composites). With reconnaissance, surveillance, and target acquisition systems becoming increasingly more sophisticated in both sensor(s) performance and processing capabilities, it is necessary to increase the camoufleur's ability to control and manipulate target signatures beyond that currently available with the lower technology materials and at a cost significantly less than that associated with the high-technology solutions. A hybrid technology is required, one that combines the best features of both technology classes--high performance at a reduced cost. This report describes such a hybrid CCD technology, that of laminated paper glass (LPG) appliqués.

Purpose

This report allows early dissemination of information relating to signature-controlling LPG appliques in camouflage, concealment, and deception. It should be recognized that LPG is a composite; as such, the physical characteristics (e.g., tensile and shear strength) and the spectral characteristics (e.g., emissivity, radar scattering coefficient, and thermal conductivity) can be controlled with great latitude by the designer. Indeed, it is the designer's ability to alter the fundamental characteristics of the LPG material that accounts for its uniqueness and maximum utility. Thus, the values presented here are representative ones based on

laboratory and field measurements, literature review, and predictive estimation determined from the performance of similar materials and modeling. This report includes a brief summary of LPG's evolution, followed by concepts of LPG employment describing retro-fitting the LPG, both as a signature manipulation appliqué and as a construction material.

2 LPG Composite Description

Basic Material Components

In its basic form, LPG consists of one central piece of heavy kraft pulp paper saturated with a mixture of monomer styrene and polyester resin, coated with fiberglass cloth laminated on either side of the paper as shown in Figure 1. Many variations of LPG appliques can be produced by inserting additional layers of material and/or applying external coatings. The following section identifies and provides information regarding the possible role each raw material plays in the LPG concept.

A 90-lb[1] weight grade of kraft paper acts as the central layer in the construction of the LPG. This paper was selected for its optical opacity, compressive strength, and absence of inert fillers. Its porous and fibrous nature contributes to the overall composite formation by providing a low-cost, easy-to-handle medium for styrene and polyester resins to permeate and create a bonding layer. The fiberglass cloth proposed for the basic LPG adds significantly to the overall shear strength and tensile strength of the composite. When combined with the paper/resin matrix, the resulting composite displays enhanced rigidity and durability. The polyester resins soak into the fibers of the treated paper to form a resin-cellulose matrix and a bonding surface for paper to the fiberglass cloth. The resin also serves as a tough, waterproof exterior layer for the composite and is translucent over a wide spectral band. This type of resin was selected for its low cost, fast curing properties, and its high bonding strength.

[1] A table of factors for converting Non-SI units of measurement to SI units is presented on page v.

Figure 1. LPG construction

Additional Signature Control Layers

The concept of LPG variations for multispectral signature control may be accomplished through material layers adhering to or sandwiched in the composite. The commercial availability of these lightweight sheets of material used for electromagnetic impulse (EMI) suggests that radar signatures could be altered if this material were incorporated into the LPG appliqué. Other possible material layers might consist of lightweight thermal insulators, fine wire mesh for increased strength and radar scattering, or air bubbles encapsulated between paper layers to alter the surface texture and yield a mottled thermal image. Two possible means of incorporating additional material layers into LPG appliqués are shown in Figure 2.

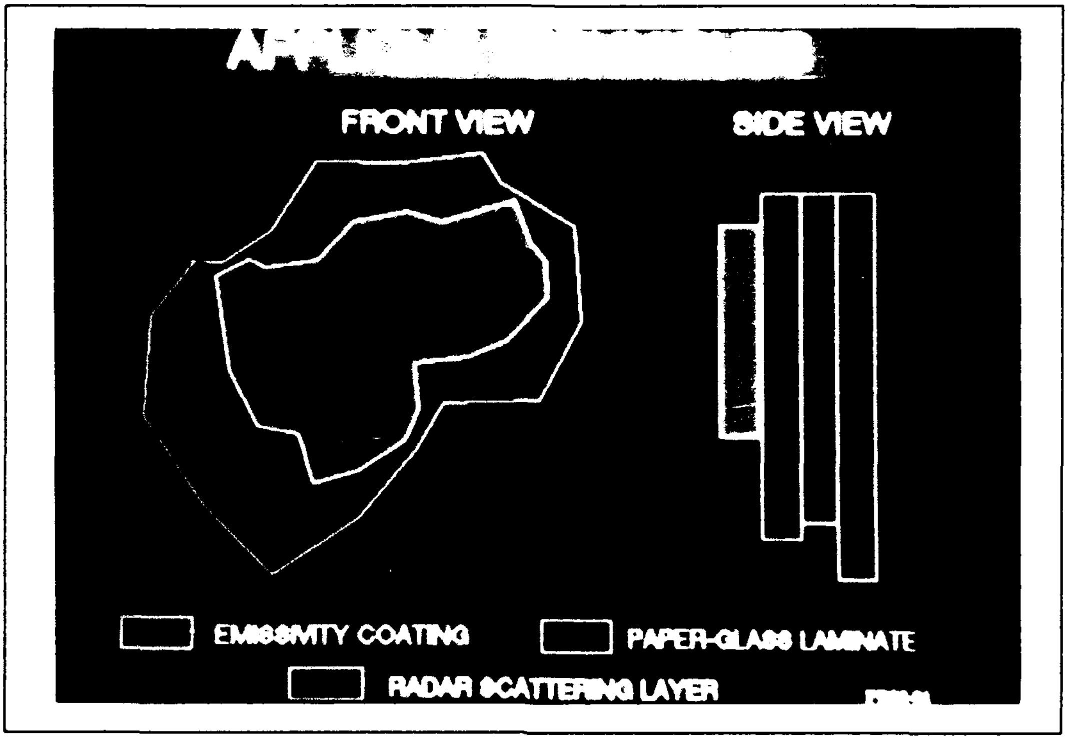

Figure 2. Multilayered LPG appliqué

External Coatings

Further multispectral signature control may be introduced to the LPG appliqué through external coatings in the form of standard camouflage paints and reduced emissivity coatings. Different paints can be applied on either side of the appliqué to increase its utility in environments which experience drastic seasonal variations in background signatures (Figures 3 and 4). For example, a northern climate may require a combination of paints, one with visual properties simulating green vegetation, the other with a snow background.

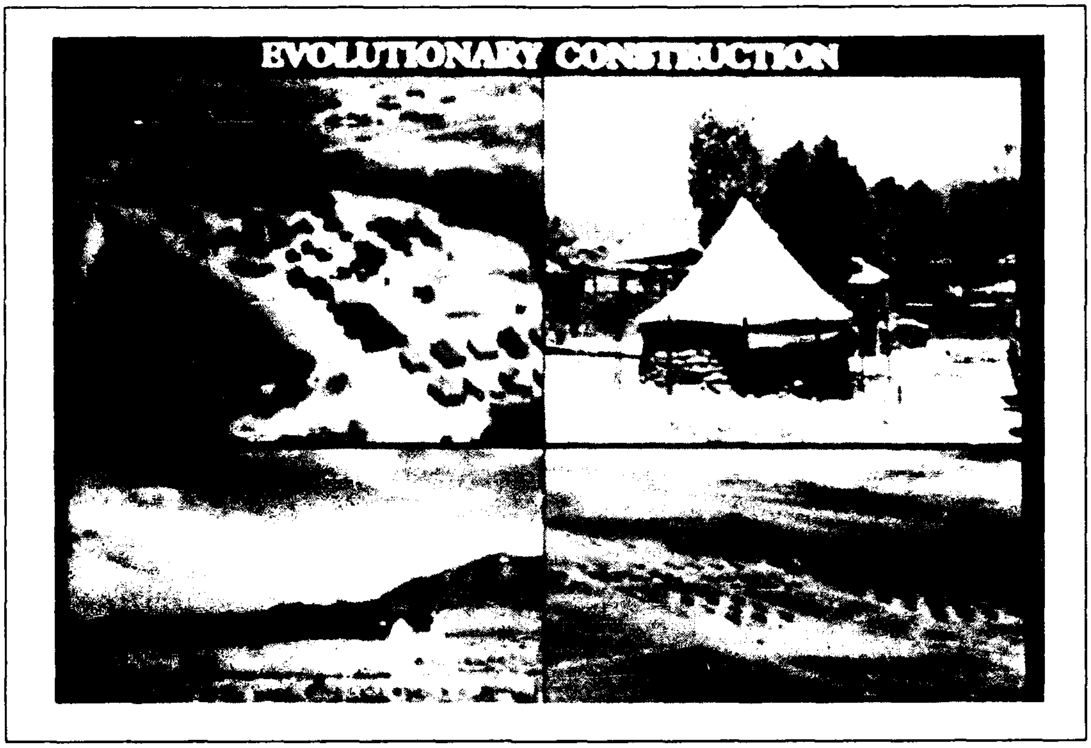

Figure 3. LPG material can be used in many areas

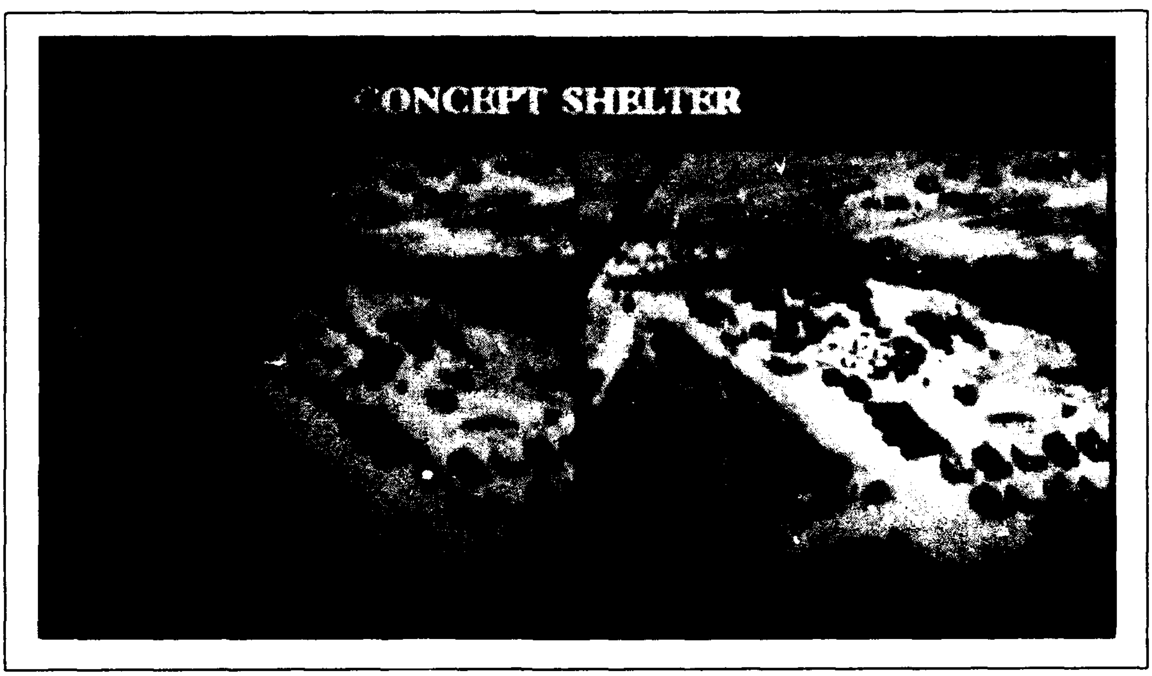

Figure 4. LPG shelter

3 Concepts of LPG Deployment

Multi-Spectral Signature Manipulation Appliqués

Hard-to-hide facilities such as power plants with smokestacks could benefit from emissivity coatings used in conjunction with LPG appliqués. Figure 5 illustrates the possible effects of LPG appliqués on just such a facility through computer image enhancement. The image shown represents a before-and-after condition using the LPG appliqué concept.

Supply depots and theater assets might benefit from LPG as illustrated in Figure 6. The image depicts a depot with class 6 bridging material as it appears before and might appear after the LPG appliqués. Note that by simulating the general outline and color schemes of billeting quarters through computer-aided image manipulation, the war-critical bridging material is rendered unrecognizable.

New Construction Material

LPG may have a role to play in the evolution of construction in new theaters of operation. The base material is intended to be provided in finished form, 4-ft by 8-ft sheets, or a formed-piece kit for assembly as structures, etc. The manufacturing processes would allow production of virtually any shape. Because the fabrication process is simple, there are many manufacturing facilities that could produce the material in either limited or bulk quantities. The process/procedure for material fabrication is very suitable for limited fabrication, possibly for testing or for a special purpose, without specialized equipment or tooling. The base material is very easy to fabricate, easy to work with, and quite versatile.

Cost is dependent upon quantity and design property (e.g., strength and spectral properties). For an appliqué that would augment/substitute for netting, the material cost for prototype quantities is approximately $1.65 per square foot for one layer of treated paper and two layers of glass (top

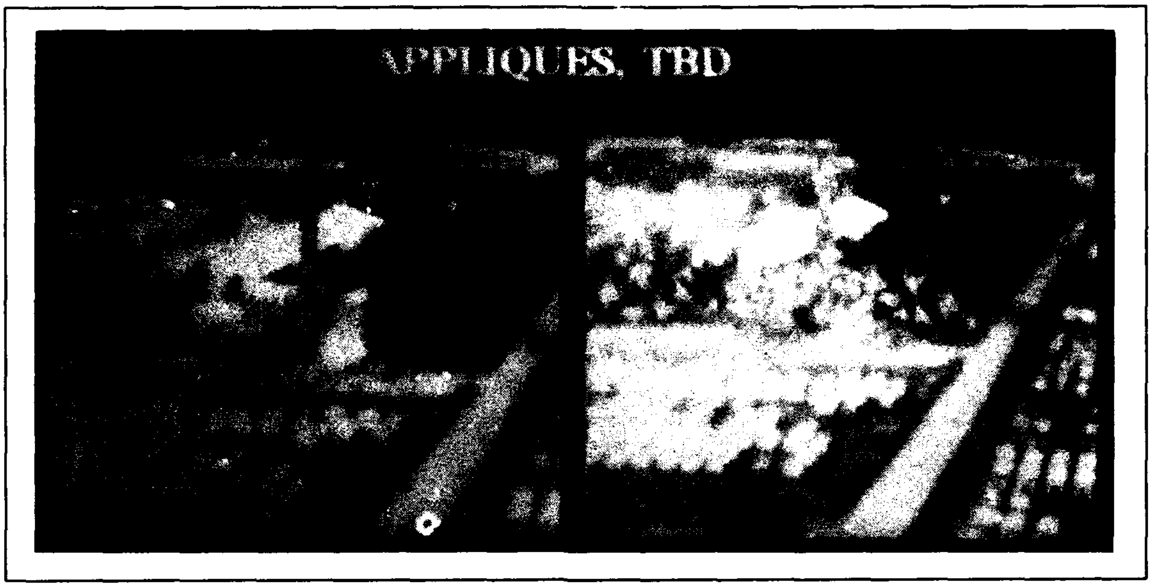

Figure 5. Computer image enhancement of LPG appliqués

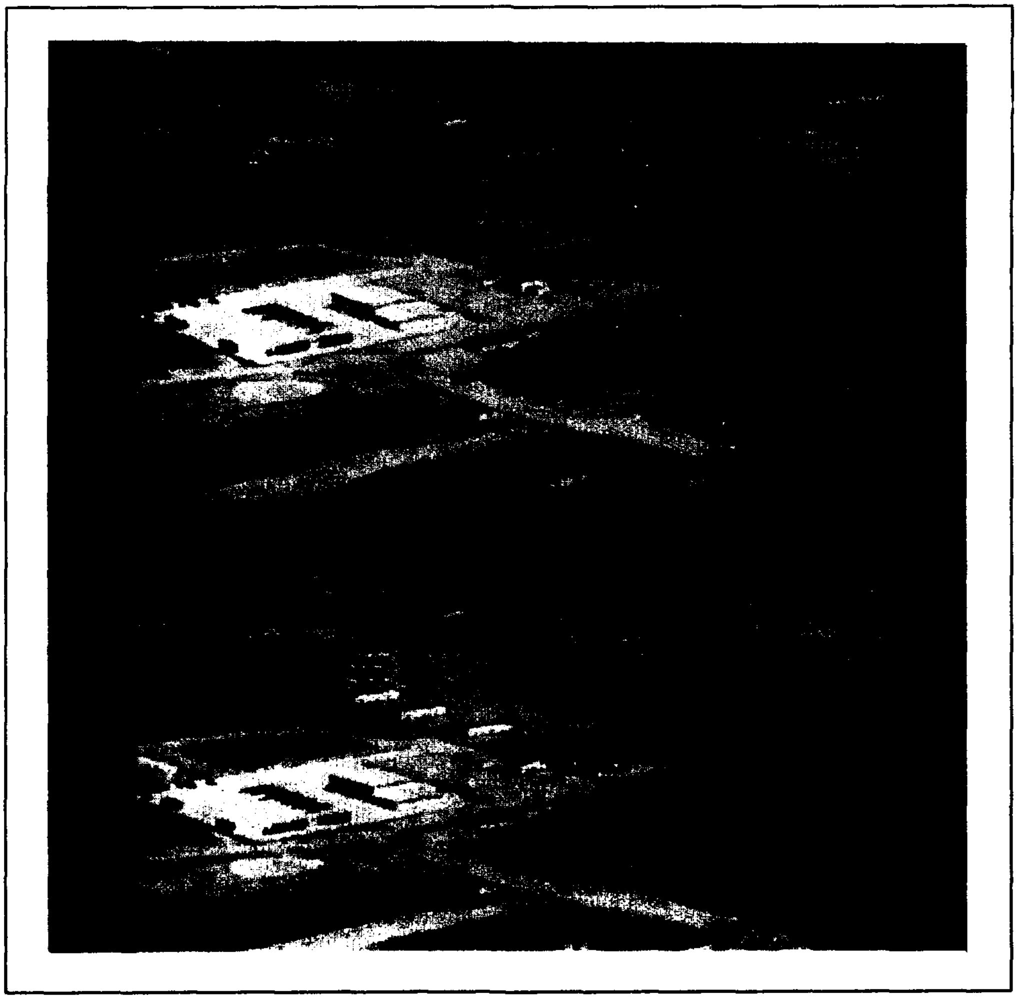

Figure 6. Computer-aided LPG appliqué placement

and bottom). Raw material cost for bulk purchases of the same material is estimated at $0.75 per square foot, with $0.25 labor/production cost per square foot, and coating/radar scattering approximately $0.50 per square foot. Production costs, at approximately $1.50 per square foot, compare quite favorably with netting, which costs from $0.85 to $4.00 per square foot for bulk quantities.

When used as a construction material and estimated with a mean thickness of 1/4 in. (four layers of paper and four layers of glass), prototype material costs $6.84 per square foot, with production costs estimated to be about $3.50 per square foot of material. For small to medium shelters (8-ft by 8-ft by 40-ft), typical of the house trailers being employed in Saudi Arabia (and other theater of operations shelters), the cost can be comparably estimated at $16K-$20K. The real advantages of an LPG shelter versus conventional construction could be reduced signatures, energy efficiency, reduced transport volume and weight, rapid, low-skill troop or indigenous labor assembly, and organic vehicle relocatability.

The concept and engineer specifications for the base LPG material should probably not be classified or restricted in distribution. This material possibly has broad civilian applications and, if manufactured, could result in reduced cost to the military.

Fixed-Facility Decoys

Fixed-facility decoys have seen limited use in the overall CCD plan, mainly because of the high cost of material and labor needed to create a convincing decoy for a last-minute deployment. Using a collapsible system of modular LPG sections with supports allows a convincing fixed-facility decoy to be deployed in a matter of hours.

4 Summary

The concept of shape-altering appliqués has been successfully employed in the past. In order to address the increasingly sophisticated reconnaissance, surveillance, and target acquisition capabilities of current and future systems, advanced appliqué systems must deliver some measure of multispectral signature control. The concepts put forth in this paper involve new materials and novel techniques that offer possible solutions for contemporary and future CCD problems.